Mirage III Flight Model Identification

<u>CREDITS</u>: I want to thanks particularly and Tom COOPER (ACIG.org) for his huge knowledge on military aerospace in general, the history of these aircraft in particular, and the fact that he build the working group.

A. Purpose and scope.

The aim of this document is to identify the Flight Model, that is Lift coefficient, Drag Coefficient et Thrust laws, for some versions of the Mirage III, and for some specific configurations.

The versions that are considered are the French air force (Armée de l'Air, aka AdA) Mirage IIIC with ATAR-9B engine, the AdA Mirage IIIE with ATAR-9C engine, the IAF (Israel) Mirage IIICJ, early version, or late, retrofitted with ATAR-9C, and the IAF (Israel) Nesher.

The IAF Mirage IIIC engine retrofit has been performed, depending on sources, after 1974 (ACIG), or after 1971 (Le Mirage IIICJ au combat)

The decision to include the late retrofitted version is lead by the fact that this is the version that had to face late Mig-21 (M, MF or bis), when original Mirage-IIIC faced Mig-21F or F-13, and this flight model identification is the basis to build a comparison between Mirage III and Mig-21M, MF and bis (the only I have reliable performance data).

The Nesher is assumed to be a locally assembled Mirage-5, with a definition equivalent to the Mirage-5F operated by the French AdA (the Mirage-5F have been built as Mirage-5J to be delivered to IAF, but due to embargo, has been retrofitted to a configuration closer to AdA standard and renamed 5F). The engine if the Nesher is also assumed to be an ATAR-9C3 or C5, similar to the one fitted in Mirage-IIIE.

The configurations to be studied are all representative of close air combat and are the following:

- A Mirage IIIC with ATAR-9B operated by AdA (French Air Force) by the end of the 60's with 2 short range A/A missiles (AIM-9B) with pylons and launchers, 2 DEFA 30mm guns with their rounds, no rocket but the rear fuel tank that take its place and half of the internal fuel.
- A Mirage IIICJ retrofitted with an ATAR-9C when operated by IAF around 1974: 2 short range A/A missiles (AIM-9B because Shafrir Mk.2 data are not known) with pylons and launchers, 2 DEFA 30mm guns with their rounds, no rocket but the rear fuel tank that take its place and half of the internal fuel.
- A Mirage IIIE with ATAR-9C operated by AdA (French Air Force) by the end of the 60's with 2 short range A/A missiles (R-550 Magic 1) with pylons and launchers, 2 DEFA 30mm guns with their rounds, no rocket but the rear fuel tank that take its place and half of the internal fuel (including leading edge fuel tanks that are optional equipment).
- A Nesher / Mirage 5F with ATAR-9C, operated by IAF in 1973: 2 short range A/A missiles (AIM-9B because Shafrir Mk.2 data are not known) with pylons and launchers.

B. Data Collection.

- Dimensional Data.

Reference Area (*S*):	34.79 m^2 (374.5 ft^2)
Wing Span (*l*) :	8.22 m
Aspect ratio ($\lambda = l^2/S$):	1.94

- Weight and Balance.

Empty Weight

Empty mean here: without fuel, or external loads, but all the rest (pilot, guns and ammo, oil and required fluids, empty optional fuel tanks).

Mirage III C and CJ

Mirage III-C empty weight is estimated from PL-P32-1 where take-off weight with 1 MATRA-530 (240kg with its pylon) and 2 AIM-9 (240Kg with pylons and launchers), is said to be 8,915 kg

If we supposed this weight being related to a plane with empty gun bay (no rounds), but with full 2,580 L of fuel (2,064 kg @ 0.8kg/l), we have, without fuel nor gun rounds, but with pilot, a weight of 6,371 kg, if we remove the pilot (95kg), we get an basic weight of 6,276 kg

- Basic weight without pilot : 6,276 kg
- Equipped Pilot : 95 kg
- DEFA Guns 250rds : 130 kg

TOTAL : 6,501 kg (14,351 lbs)

Mirage III E

From Mirage-IIIE at page PL-II-3

-	Basic weight without pilot	: 6,665 kg
-	Equipped Pilot	: 95 kg
-	Rear fuselage fuel tank	: 90 kg
-	Leading edge fuel tank	: 150 kg
-	DEFA Guns (Chassis canon) w 250rds	: 360 kg

TOTAL : 7,360 kg (16,247 lbs)

Nesher - Mirage 5F

From Mirage-5F “Manuel d’Utilisation” at page PL-II-3:

-	Basic weight with 95 kg pilot	: 6,780 kg
-	DEFA Guns rounds (250)	: 130 kg

TOTAL : 6,910 kg (15,253 lbs)

Comment: In the maintenance manual of the Mirage-5F the empty weight is said 100kg lighter (6,680 kg) with pilot and seat. As I’ve defined Mirage IIIE weight from its Manuel d’Utilisation and not from its Maintenance one (GCB), I’ll do the same for the Mirage-5F / Nesher.

Fuel Weight

Mirage III C and CJ

With the “Chassis canon” (guns), the front fuselage tank (325 L) is removed, but without the SEPR rocket, the rear fuselage tank (460 L) can be installed. The leading edge tanks do not exists on Mirage III C.

Fuel density of 0.8kg/l is assumed.

-	Wings	: 2 x 545 L =	1,090
-	Fuselage (main)	: 2 x 515 L =	1,030
-	Rear Fuselage	:	460

TOTAL : 2,580 L (2,064 kg or 4,556 lbs)

Mirage III E

With the “Chassis canon” (guns), the front fuselage tank (325 L) is removed, but without the SEPR rocket, the rear fuselage tank (545 L) can be installed. The two 125 L leading edge tanks are installed.

Fuel density of 0.8kg/l is assumed.

-	Wings (with leading edge)	: 2 x 670 L =	1,340
-	Fuselage (main)	: 2 x 515 L =	1,030
-	Rear Fuselage	:	545

TOTAL : 2,915 L (2,332 kg or 5,147 lbs)

Nesher - Mirage 5F

Mirage 5 definition is based on late Mirage IIIE (SN#546) that implies the two 125 L leading edge tanks are installed. The “Chassis canon” (guns) is not removable, so no front fuselage tank (325 L), but the rear fuselage tank (545 L) is installed as the SEPR rocket bay can’t be. The electronic bay behind the pilot seat is replaced in the Mirage 5 by a Top fuselage 465l fuel tank (electronic devices are fewer and moved to the nose that does not include the radar any more).

Fuel density of 0.8kg/l is assumed.

-	Wings (with leading edge)	: 2 x 670 L =	1,340
-	Fuselage (main)	: 2 x 515 L =	1,030
-	Top Fuselage	:	465
-	Rear Fuselage	:	545

TOTAL : 3,380 L (2,704 kg or 5,969 lbs)

Load-out Weight

Same for all Nesher, Mirage 5F and Mirage IIIC versions and described in Mirage-IIIE at page PL-II-3

-	Sidewinder AIM-9B:	80kg
-	Pylon + launcher:	30kg

TOTAL : 2 x 110kg (220kg/486lbs)

For the AdA Mirage IIIE

-	R-5550 Magic-I	: 89 kg
-	Launcher type 40	: 39 kg
-	CES3 Pylon + Adaptor (ADP4)	: 36 kg

TOTAL : 2 x 164kg (328kg/724lbs)

Gross Weight.

Mirage III C & CJ

In a configuration with 2xAIM-9, GW can vary (depending on internal fuel) between 8,785 kg (19,393 lbs) at take-off (100% of internal fuel) and 6,721 kg (14,837 lbs) with no fuel.

So, Combat configuration (50% internal fuel) gross weight is 7,753 kg (17,115 lbs)

Mirage III E

In a configuration with 2xR-550, GW can vary (depending on internal fuel) between 10,020 kg (22,119 lbs) at take-off (100% of internal fuel) and 6,721 kg (14,837 lbs) with no fuel.

So, Combat configuration (50% internal fuel) gross weight is 8,854 kg (19,545 lbs)

Nesher - Mirage 5F

In a configuration with 2xAIM-9, GW can vary (depending on internal fuel) between 9,834 kg (21,709 lbs) at take-off (100% of internal fuel) and 7,130 kg (15,740 lbs) with no fuel.

So, Combat configuration (50% internal fuel) gross weight is 8,482 kg (18,724 lbs)

- Speed and Load Factor limitations.

They are assumed to be the same for all AdA versions and described in Mirage-IIIE at page PL-III-1, 2 and 3.

For clean aircraft, speed limitations are defined by:

- IAS < 750Kts
- Mach number < 2.0

For a configuration with R-550, speed limitations are equal to the clean one:

- IAS < 750Kts
- Mach number < 2.0

For a configuration with AIM-9, speed limitations are defined by:

- IAS < 700Kts
- Mach number < 2.0

In RAAF Mirage IIIO Manual (AAP 7213.003-1, page AL-31 5.3) the speed limitations for the same 2xAIM9 configuration (identified as SW for Sidewinder) is declared to be:

- IAS < 730Kts
- Mach number < 2.0

Based on the assumption that limitations to be used by IAF pilots in 1974 should be closer to an 1978's Export Manual than a AdA 1965's one, I will keep the RAAF values for the IAF Mirage III C with ATAR 9C.

Load factor limitations are the same for clean aircraft of for AIM-9 configuration and only depend on gross weight:

- GW < 9,500kg (20,971lbs), Ng in [-3.5;+6.7]
- GW > 9,500kg (20,971lbs), Ng in [-2.7;+5.5]

- Angle of attack (AoA)

The Angle of Attack value (incidence, AoA), is not displayed to the pilot in an angular value.

The ADHEMAR device is using three lights (green, amber and red) that switch on an off depending on incidence.

Values for which these events occur are not expressed in True AoA angular value (deg), but in Sector AoA (also in deg), the relation between "True AoA" (AoA_T) and "Sector AoA" (AoA_S) is described in Mirage-IIIE at page PL-G-14. It's a linear relation:

AoA_S (AoA_T = 0 deg) = 0 deg.
AoA_S (AoA_T = 18 deg) = 30 deg.

$$AoA_S = \frac{5}{3}.AoA_T \ or \ AoA_T = \frac{3}{5}.AoA_S$$

- Lift coefficient versus AoA.

Lift coefficient will be computed for Mirage III-E and then applied to all other variants.

From MIRAGE III-E, at page PL-G-13, we have the relation between true incidence, Mach number, load factor and gross weight.

We will consider a CoG location at 50% of MAC, a gross weight of 9,000kg. For each Mach number, we read true incidence corresponding to a given load factor, that compute C_z value from load factor by:

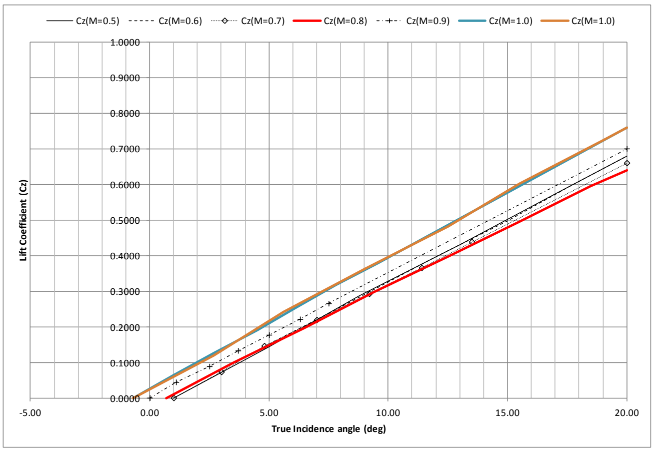
$$(e.1)\ \frac{2.M.g}{\rho.S.V^2} = C_z$$

Where M is the mass (gross weight) in kg, S reference surface in m^2, ρ air volumic mass in kg/m^3, g gravity acceleration = 9.81 m/s^2.

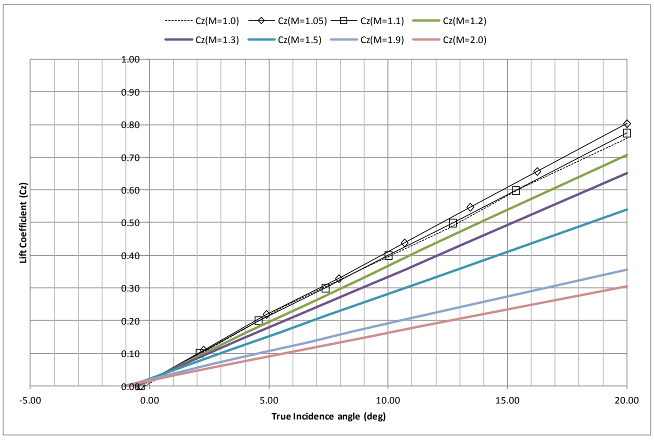
First set of computation will be done for Mach number between 0.5 and 1.0, when possible two altitudes will be used.

With load factor between 1 and 6, we can get Lift values for incidence between 1.00 and 19.00 degrees, as all results show clearly a strict linear correlation between incidence and lift coefficient within this range, values have been extrapolated up to a true incidence of 20.00 degrees (AoA_S of 33.33) and down to null lift.

Results are summarized in the following figure:



The second set of measures is related to the supersonic domain (Mach number between 1.05 and 2.0, using M=1.0 as a reference).



Then the last question to be answered is: what happen for true incidence greater the 20 deg (AoA_S of 33) ?

I do not have any document describing Mirage III behavior in such a domain, so I will use a comparative method, using the Mig-21 as reference.

Mig-21 lift at medium mach number (around M0.6 when auto flaps device is not activated) laws seems to be quite similar to the one of the Mirage III in the low incidence domain : null lift close to null incidence, linear relation between lift coefficient and incidence sector up to 28. From an index incidence of 33 to 42, the Mig-21 lift coefficient at M=0.6 increase from 0.811 to 0.955, corresponding to +17.5%.

If we transpose that to the Mirage III, we can suppose that increase the sector incidence from 33 to 42 (so true incidence from 20 to 25.2 deg corresponding to +26%) will also lead to an increase of the lift coefficient of +17.5%.

- AoA limitations.

The AOA limitations to be followed by the pilot are documented in Mirage-IIIE at page PL-III-1, 2 and 3.

For all configurations with 2xAIM-9 or 2xR-550, they are identified as “amber light switching off”, so equivalent to a Sector AoA of 25 deg. (generally equivalent to a True AoA of 15 deg).

The True incidence values corresponding to Amber extinction depending on Mach number are described in MIRAGE III-E, at page PL-G-13.

Here are the extracted values:

Mach	AoA_T	AoA_S
0.30	15.45	25.75
0.40	15.96	26.59
0.50	16.63	27.72
0.60	17.30	28.84
0.70	18.09	30.15
0.80	18.71	31.18
0.90	19.33	32.21
1.00	18.26	30.43
1.10	16.35	27.25

Limits for Mach number under 0.30 will be set to 15.45 (AoA_T), and over 1.10 set to 16.35 AoA_T.

These limitations will be used to compute flight envelope of both Mirage III-C and III-E used in the French Air Force (AdA).

According to discussion between Israel Air Force pilots and Swiss ones, it appears that IAF has experienced higher incidence values than the one recommended by the manufacturer. The limit Sector Incidence has been moved from Amber extinction up to 42 (corresponding to a true incidence limit moved from 15-19 to 25.2 deg.) This is very similar with what happen with Mig-21, where index incidence limit, recommended as 28, can be moved up to 55.

Under these assumptions, Mirage III-CJ incidence limitations to be considered have to be 25.2 deg of true incidence, or 42 sector incidence. This is also assumed to be the case for IAF Nesher.

There are other factor that limit the incidence of a Mirage III: first one is the elevon efficiency in low dynamic pressure that prevent a/c to reach its maximum incidence at very high flight level, the second being related to actuator saturation at high dynamic pressure that prevent the a/c to reach high incidence at high indicated speed, especially in supersonic and low altitude domain.

Because these limitations are not easy to model and have few impact on the [M0.2; M1.0] x [SL; FL350] domain that is my main focus, they will not be taken into account to compute A:C performances.

C. Mirage-III E with ATAR-9C

- Max A/B Thrust and Drag coefficient.

Seal level (1,000ft)

We start by Mirage III-E at 1,000ft, described in Mirage-IIIE at page PL-A1.1

Diagram start from take-off at a gross weight of 9,145kg and give speed (CAS) along time (s) and fuel spent (allowing estimation of the weight along time with an indicated density of 0.77 kg/L).

For each point in time, the true speed (V in m/s) and acceleration (dV/dt in m/s^2) can be estimated by linear interpolation, and then, we can compute the Extra Specific Power (Ps in m/s) according to:

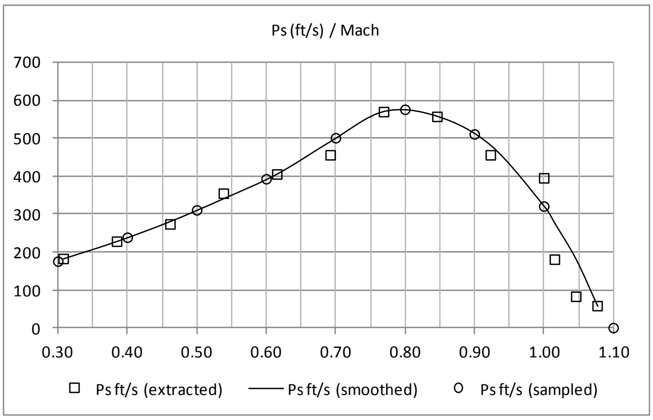
$$(f.1)\ Ps = \frac{1}{g} V.\frac{dV}{dt}$$

Where g = gravity acceleration = 9.81 m/s^2.

Data extracted from this figure can be summarized by this table (with Ps values converted in f/s and weight in lbs):

t (s)	CAS (Kts)	Ps (ft/s)	Fuel spent (L)	Weight (lbs)
30	200	182	133	19,961
35	250	228	156	19,923
40	300	273	178	19,885
45	350	354	200	19,848
49	400	405	222	19,810
54	450	455	250	19,763
58	500	569	279	19,714
62	550	556	306	19,667
67	600	455	338	19,614
74	650	394	386	19,532
76	660	180	400	19,508
84	680	83	450	19,423
106	700	58	600	19,168

The extracted data are now smoothed and resample in the following figure:



Providing, for each Mach value, the corresponding Ps value at a given gross weight, summarized in this table:

Mach	Ps ft/s (sampled)	Est. Weight
0.30	175	19,961
0.40	238	19,916
0.50	310	19,870
0.60	392	19,800
0.70	500	19,763
0.80	575	19,702
0.90	510	19,593
1.00	320	19,532
1.10	0	19,168

It is now possible, for a given mach number to evaluate the corresponding thrust and drag giving the expected Ps value at the related weight.

From the simplified force equation (M mass in kg, S reference surface in m², Thrust force in N, ρ air volumic mass in kg/m³:

$$(f.2)\begin{cases} M.g = \frac{1}{2}\rho C_z S V^2 \\ M.\frac{dV}{dt}(t) = \left(Thrust - \frac{1}{2}\rho C_x S V^2\right) \end{cases}$$

We can express the relation between Drag, thrust and Ps (in m/s):

$$(f.3)\ Ps = \frac{V}{M.g}.\left(Thrust - \frac{1}{2}\rho C_x S V^2\right)$$

The drag force cannot be supposed exactly deduced form the minimum drag coefficient (null lift drag) as a small amount of lift is required, even for such a 1G acceleration fly path.

The lift coefficient will be directly deduced from the gross weight and speed in *(f.2)*, lift due to thrust upward orientation with AoA will be neglected, so we will use a simplified Drag coefficient formulation:

$$(f.4)\ C_x(Ma, AoA) = C_{x0}(Ma) + k(Ma).C_z(Ma, AoA)^2$$

With $k = \frac{1}{\pi.\lambda.e}$ where $\lambda = \frac{l^2}{S}$ is the aspect ratio (here 1.94) and (e) the wing efficiency (between 0 and 1)

So we reach the following equation system to be solved:

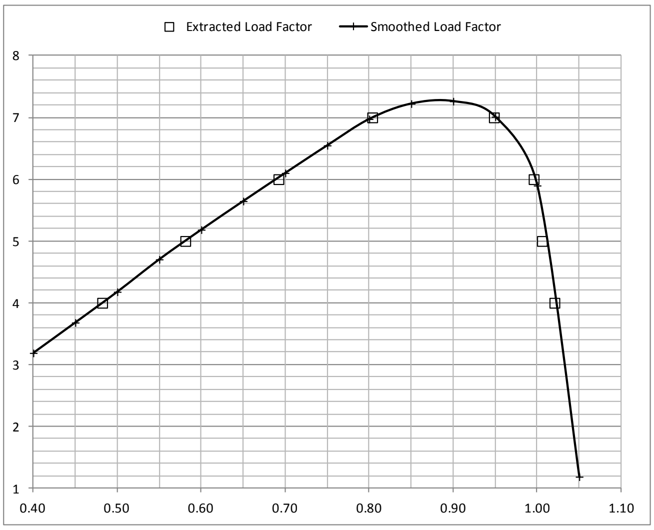
$$(f.6)\begin{cases} C_z = \frac{2.M.g}{\rho(z).V^2} \\ Th(Ma) = Ps.\frac{M.g}{V} + \frac{1}{2}.\rho(z).(C_{x0}(Ma) + k(Ma).C_z{}^2).S.V^2 \end{cases}$$

Meaning that, for all Mach value, we have one equation with 3 values to find (*Thrust, C_{x0}* and *k*)

Even if we assume that C_{x0} and k are common to a large range of Mach number (from 0 to 0.7), we will still have more unknown values (2) than equations.

In order to get the missing conditions, we will analyze the sustained load factor at sea level described in Mirage-IIIE at page PL-A1.11 (for a gross weight of 8,175kg / 18,046 lbs)

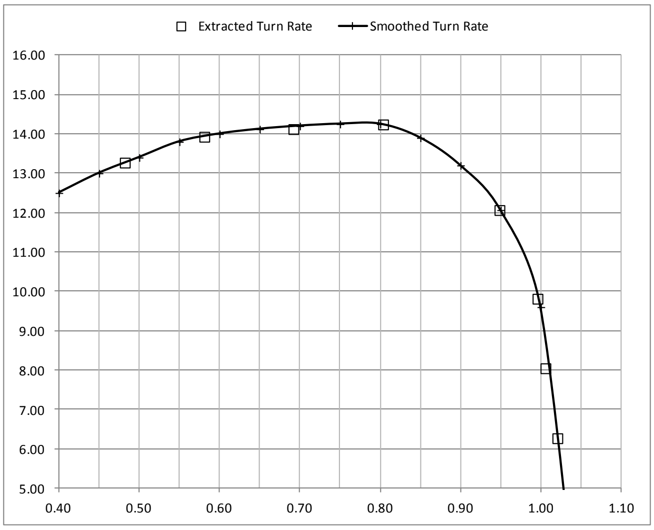
The sustained load factor extracted from the diagram can be smoothed and sampled through the following figure:



Corresponding to the following values:

Mach	Smoothed Load Factor
0.40	3.19
0.50	4.18
0.60	5.18
0.70	6.10
0.80	6.97
0.90	7.26
1.00	5.90

We can compute sustained turn rate from load factor, and get the following figure:



For each Mach number we get the following equations:

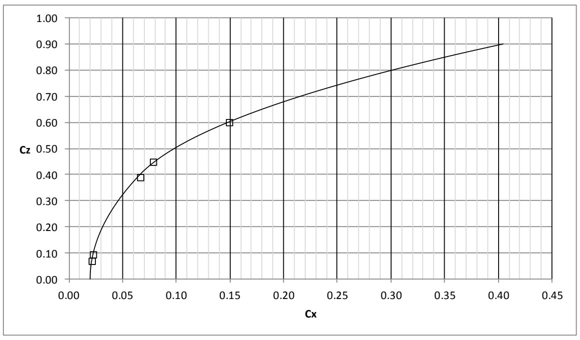
$$(f.7)\begin{cases} C_z = \dfrac{2.M.g.N_g}{\rho(z).V^2} \\ Th(Mach) = \dfrac{1}{2}.\rho(z).(C_{x0}(Mach) + k.C_z{}^2).S.V^2 \end{cases}$$

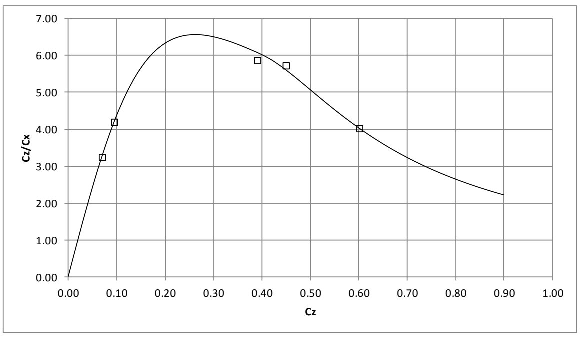
Focus on Mach number 0.6 and 0.7, with Sustained load factor and Extra Specific Power, give 4 equations and allow computation of the 4 unknown values:

- Cx0 = 0.02
- k = 0.29
- Thrust(M=0.6) = 16,000 lbs
- Thrust(M=0.7) = 18,500 lbs

Then we include all mach value equations (Ps and Ng) to determine Thrust values and improve the Drag Coefficient law for higher lift.

$$(f.8)\ C_x = 0.02 + 0.29.C_z{}^2 + 0.6.Max(0, C_z - 0.4)^2$$





Last, we have to balance Thrust curve and null lift drag for Mach number over 0.8 up to 1.10.

At the end of this iterative process, we have frozen:

- The null lift Drag coefficient value along Mach from 0 to 1.10 : $C_{x0}(Mach)$

- The relation between Lift and Drag coefficient
  Mach number in [0.00;0.85]
  $(f.9)\ C_x = C_{x0} + 0.29.C_z{}^2 + 0.6.Max(0, C_z - 0.4)^2$
  Mach number in [0.90;1.10]
  $(f.10)\ C_x = C_{x0} + 0.27.C_z{}^2 + 0.6.Max(0, C_z - 0.4)^2$

- The Thrust (Maximum A/B) values along Mach number at sea level.

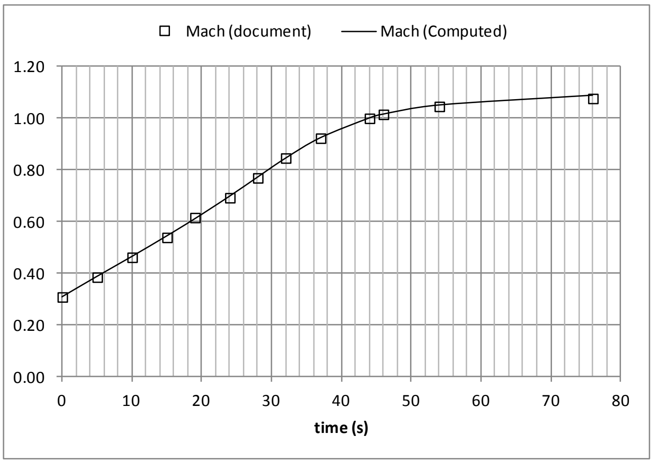
Then, in order to check the complete model with the values extracted from the Manuals, we will compute Extra Specific Power and Maximum sustained load factor and turn rate using the non simplified equations:

$$(f.10)\begin{cases} \frac{1}{2}.\rho(z)C_z.S.V^2 + Th.\mathrm{Sin}(AoA) = M.g \\ Thrust.Cos(AoA) = Ps.\frac{M.g}{V} + \frac{1}{2}.\rho(z).C_x.S.V^2 \end{cases}$$

$$(f.11)\begin{cases} \frac{1}{2}.\rho(z)C_z.S.V^2 + Th.\mathrm{Sin}(AoA) = N_g.M.g \\ Thrust.Cos(AoA) = \frac{1}{2}.\rho(z).C_x.S.V^2 \end{cases}$$

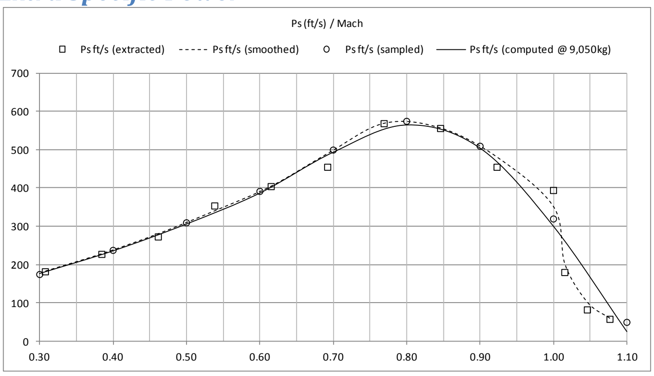
Here are the graphics and tables that compare performances forecasted by the model with the one extracted from the manual (even if smoothed or sampled).

Acceleration



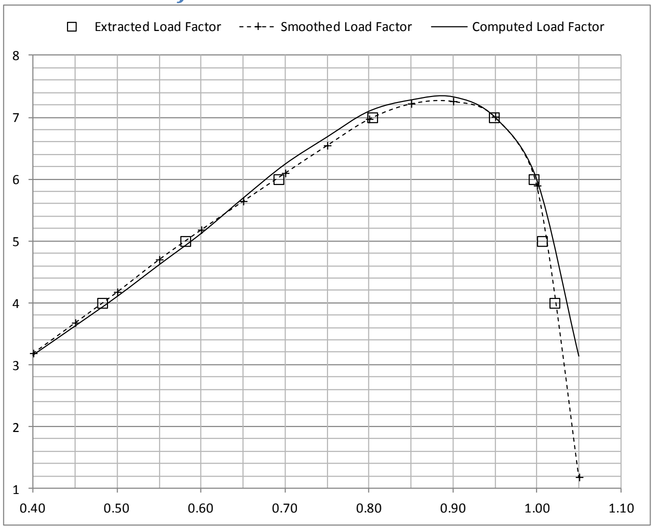
t (s)	Mach (document)	Mach (Computed)	Error
0	0.31	0.31	0.0%
5	0.38	0.39	0.6%
10	0.46	0.46	0.7%
15	0.54	0.54	1.5%
19	0.62	0.61	-2.0%
24	0.69	0.70	1.5%
28	0.77	0.77	0.4%
32	0.85	0.84	-0.8%
37	0.92	0.92	0.0%
44	1.00	1.00	-0.2%
46	1.02	1.01	-0.3%
54	1.05	1.05	1.2%
76	1.08	1.09	3.5%

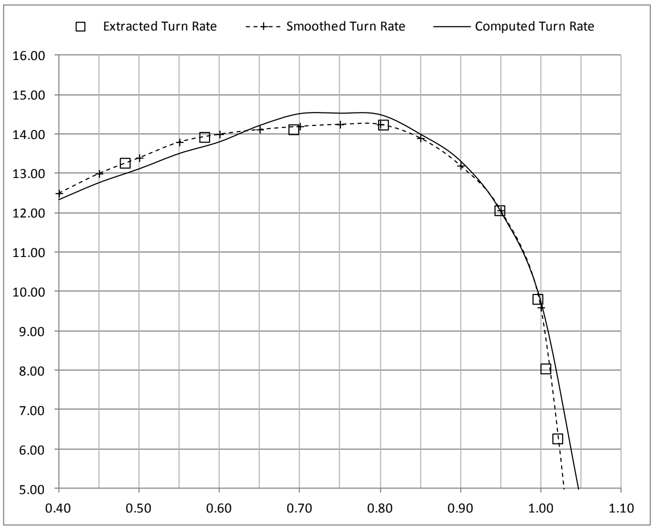
Extra Specific Power



Mach	Ps ft/s (sampled from Manual)	Ps ft/s (computed @ 9,050kg)	Error
0.30	175	176	0.7%
0.40	238	235	-1.1%
0.50	310	306	-1.4%
0.60	392	387	-1.3%
0.70	500	494	-1.2%
0.80	575	565	-1.7%
0.90	510	505	-1.0%
1.00	320	300	-6.2%

Sustained load factor and turn rate





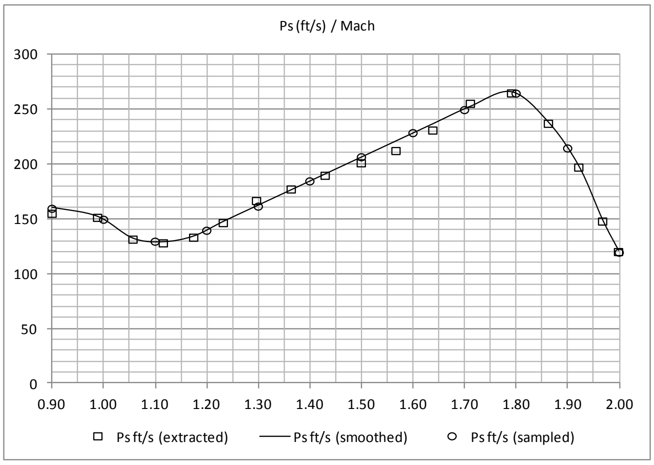
Mach	Turn Rate (Forecast)	Load Factor (Forecast)	Turn Rate (Smoothed Manual)	Load Factor (Smoothed Manual)	Error (T)	Error (Ng)
0.40	12.33	3.15	12.50	3.19	-1.3%	-1.2%
0.45	12.76	3.62	13.00	3.68	-1.8%	-1.7%
0.50	13.12	4.09	13.40	4.18	-2.1%	-2.0%
0.55	13.51	4.61	13.80	4.70	-2.1%	-2.0%
0.60	13.80	5.11	14.00	5.18	-1.4%	-1.4%
0.65	14.22	5.68	14.12	5.65	0.7%	0.7%
0.70	14.52	6.23	14.20	6.10	2.2%	2.2%
0.75	14.53	6.67	14.25	6.55	2.0%	1.9%
0.80	14.49	7.09	14.25	6.97	1.7%	1.7%
0.85	14.00	7.27	13.90	7.22	0.7%	0.7%
0.90	13.32	7.32	13.20	7.26	0.9%	0.9%
0.95	12.04	6.99	12.07	7.01	-0.2%	-0.2%
1.00	9.75	5.98	9.60	5.90	1.5%	1.5%

At 36,000ft

Thrust at 36,000ft and null lift Drag coefficient (Cx0) will be determined using acceleration diagram from M0.9 to 2.0 described in Mirage-IIIE at page PL-A1.13 (for a gross weight of 8,600kg at run start.

From this diagram we compute Extra specific power (Ps) in the following table and curves:

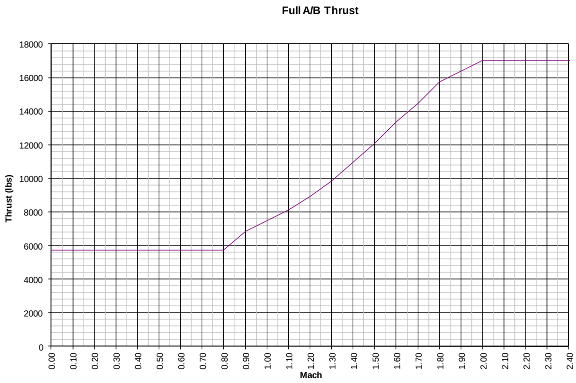
Mach	Ps ft/s (sampled)	Est. Weight
0.90	160	18,985
1.00	150	18,918
1.10	130	18,830
1.20	140	18,708
1.30	162	18,595
1.40	185	18,487
1.50	207	18,361
1.60	229	18,220
1.70	250	18,084
1.80	265	17,944
1.90	215	17,752
2.00	120	17,455



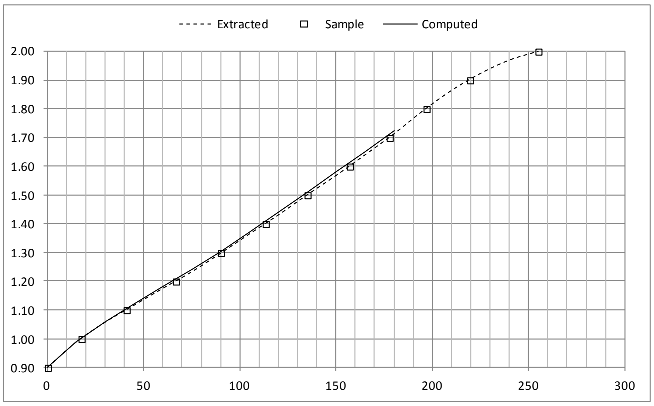
We add, from sustained load factor diagram in Mirage-IIIE at page PL-A1.11 (for a gross weight of 8,175kg / 18,046 lbs), that sustained load factor at M0.8 is around 1.9G, and last we consider that thrust is constant for mach number bellow 0.8.

The Null lift Drag coefficient variation along the complete Mach range is chosen as:

The Thrust curve:



And this allows to simulate the acceleration run from M0.9 and to compare forecasted values with the one from the manual:

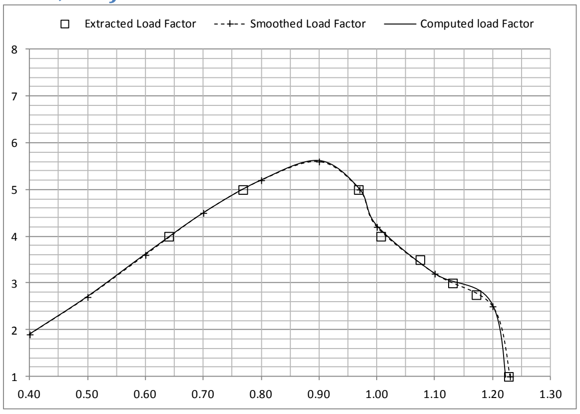


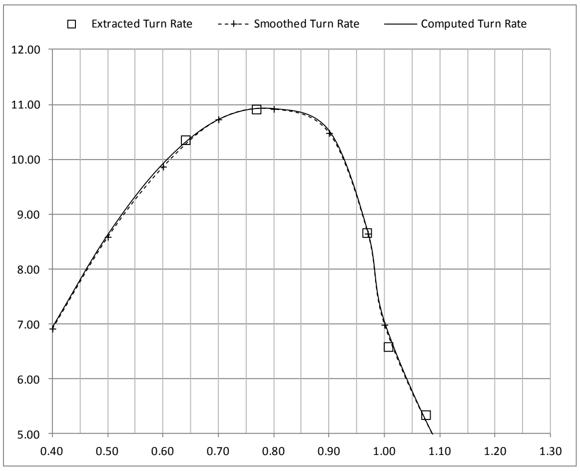
t (s)	Mach (extracted)	Ps ft/s (smoothed)	Mach (Computed)	Error
0	0.90	160	0.90	0.0%
15	0.99	152	0.99	-0.1%
30	1.06	132	1.06	0.1%
45	1.12	128	1.12	0.4%
60	1.17	134	1.18	0.5%
75	1.23	147	1.24	0.6%
90	1.30	161	1.30	0.5%
105	1.36	176	1.37	0.5%
120	1.43	190	1.44	0.7%
135	1.50	206	1.51	0.6%
150	1.57	220	1.58	0.7%
165	1.64	236	1.65	0.8%
180	1.71	252	1.72	0.7%

Other altitudes.

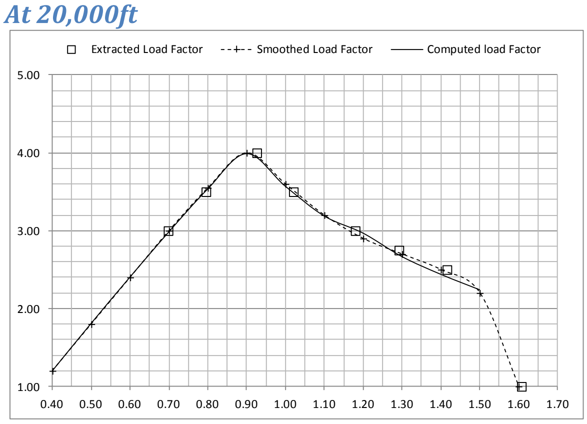
Here, the Thrust curve will be determined using Sustained load factor bellow at 10,000, 20,000 and 30,000ft.

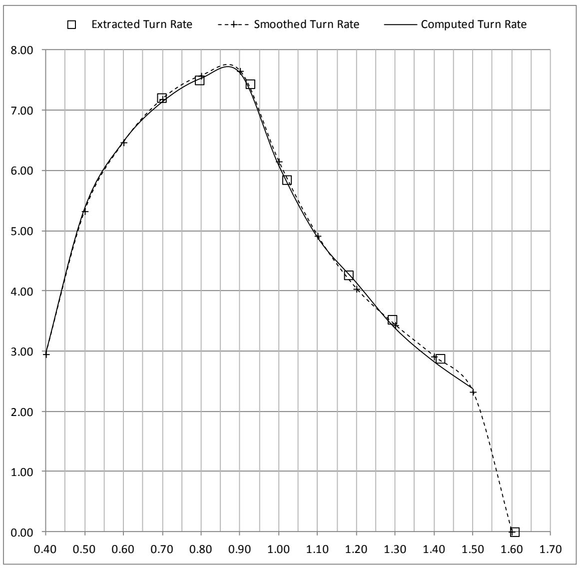
At 10,000ft



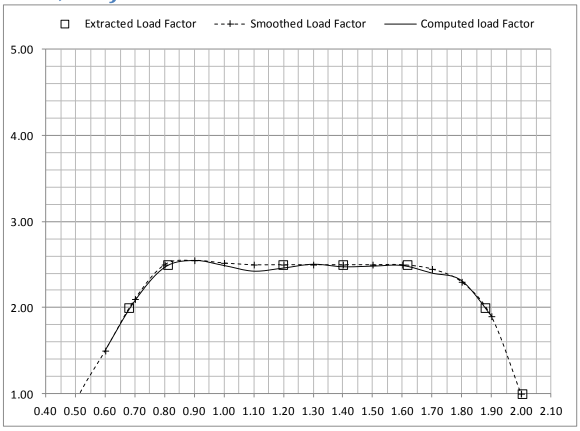


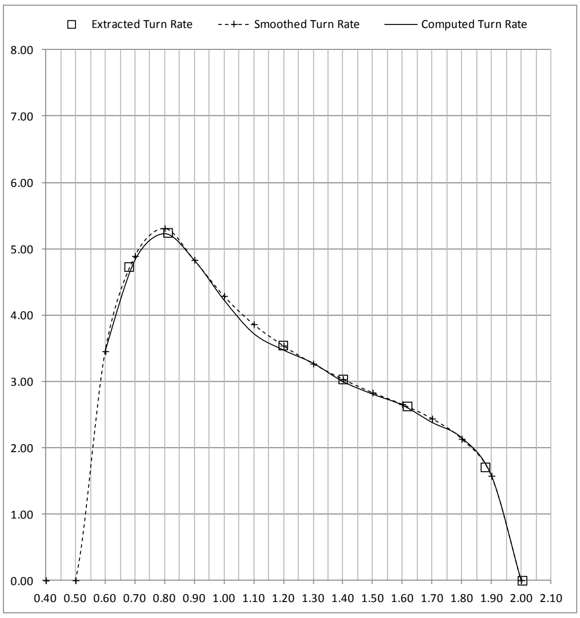
At 20,000ft





At 30,000ft

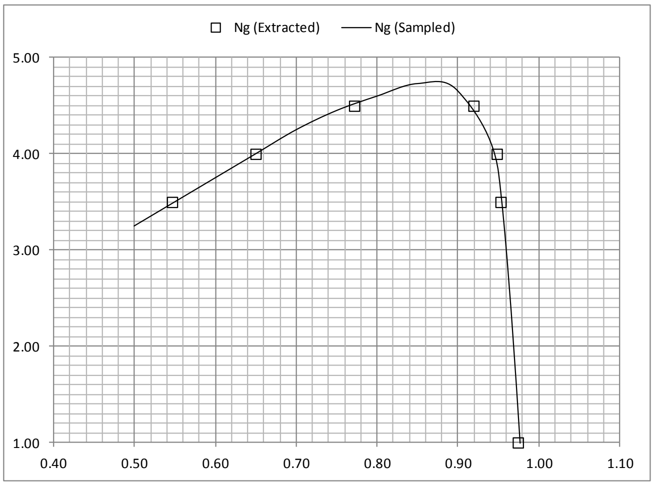




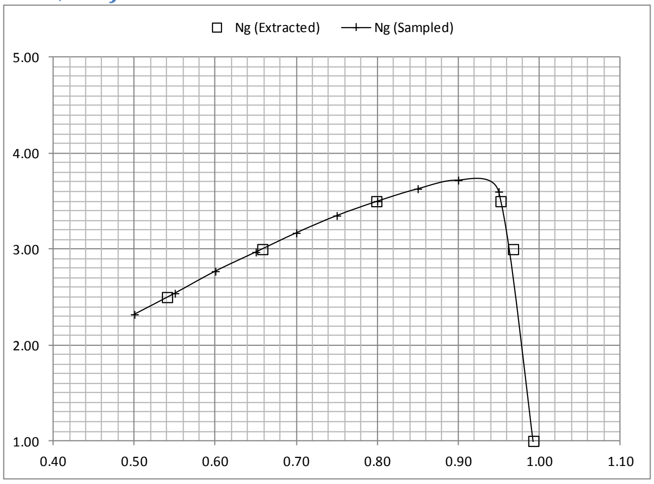
Military Thrust

Military Thrust is computed to fit the sustained load factor values described in Mirage-IIIE at page PL-A1.9 (for a gross weight of 8,175kg / 18,046 lbs).

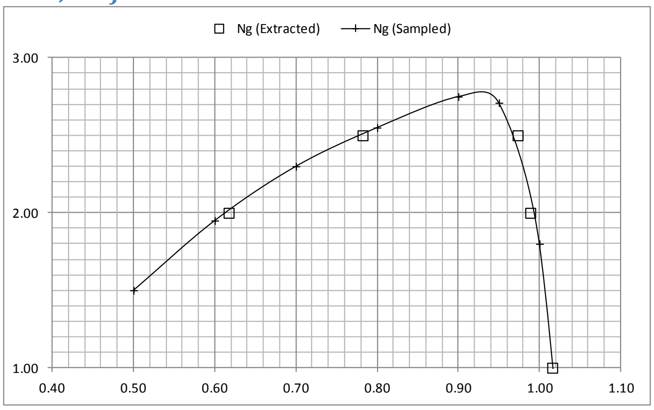
At Sea Level



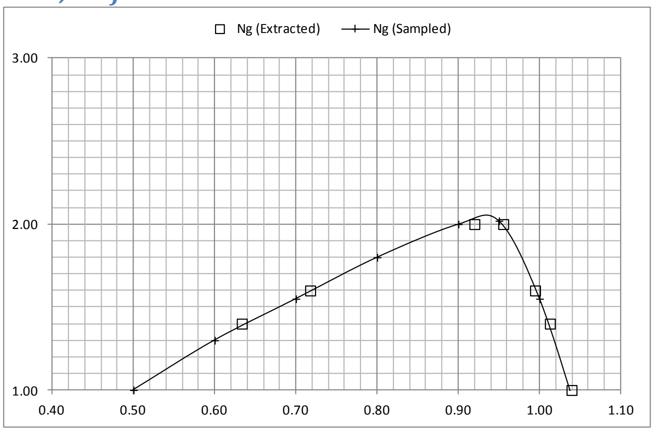
At 10,000ft



At 20,000ft



At 30,000ft



For higher altitude the same variation along Mach number is kept, maximum value is defined to fit maximum speed.

- External loads Drag.

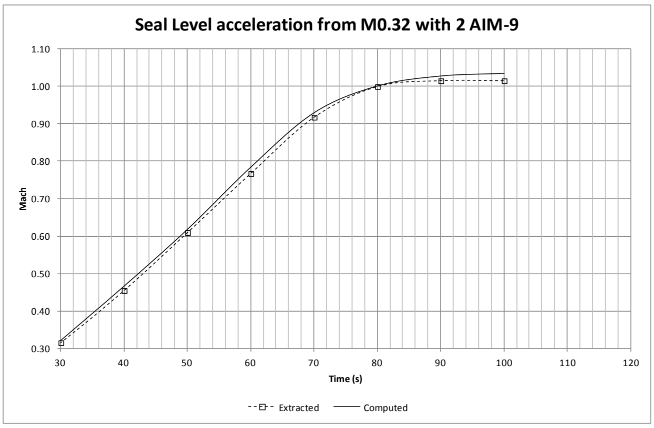
Definition of impact of external loads (here 2 AIM-9 or R-550 with their rail and pylons) is deduced from Full A/B acceleration figures in Mirage-IIIE at page PL-A3.1 for 1,000ft and PL-A3-13 at 36,000ft (related to the Sidewider configuration).

The following figures show acceleration values comparison between those read from manual and those forecasted while applying the following rule:

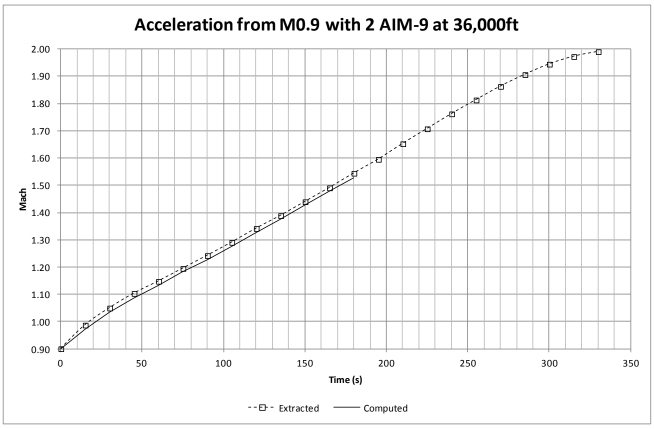
When Mach number is under 0.9, each AIM-9 or R-550 with its pylon and rail add 0.001 to the airplane Cx.

When Mach number is between 0.9 and 1.05, each AIM-9 or R-550 with its pylon and rail add 0.002 to the airplane Cx.

When Mach number is over 1.05, each AIM-9 or R-550 with its pylon and rail add 0.00125 to the airplane Cx.



t (s)	Mach (Extracted)	Mach (Computed)	Error
30	0.32	0.32	0.0%
40	0.46	0.47	2.2%
50	0.61	0.62	1.1%
60	0.77	0.78	2.0%
70	0.92	0.93	1.2%
80	1.00	1.00	0.0%
90	1.02	1.03	1.1%
100	1.02	1.03	1.8%



t (s)	Mach (Extracted)	Mach (Computed)	Erreur
0	0.90	0.90	-0.1%
15	0.99	0.97	-1.5%
30	1.05	1.03	-1.5%
45	1.10	1.09	-1.7%
60	1.15	1.13	-1.2%
75	1.20	1.18	-1.2%
90	1.24	1.23	-1.2%
105	1.29	1.28	-1.2%
120	1.34	1.33	-1.3%
135	1.39	1.38	-0.9%

150	1.44	1.43	-0.9%
165	1.49	1.48	-0.9%
180	1.54	1.53	-1.2%

D. Mirage-III C with ATAR-9B

All aerodynamic data will be kept from Mirage-IIIE to Mirage-III C, we only have to recomputed Thrust data (Full A/B and Military).

The thrust values will be determined using performances diagram for clean aircraft from Mirage-III C :

- PL-P2.1: Acceleration at sea level, GW=8,250kg
- PL-P2.7: Acceleration at 36,000ft.
- PL-P2.10: Sustained load factor at MIL Thrust
- PL-P2.12: Sustained load factor at Max A/B Thrust

The gross weight is only known for the first diagram, so we will consider that the weight differences is the same as the one we can compute from M-III E between the two acceleration diagram:

- Acceleration at sea level, GW=9,145kg
- Acceleration at 36,000ft, GW=8,600Kg (-545 kg)

Concerning the Sustained Load factor diagram we will use the gross-weight that allow the best fitting with the thrust values computed from acceleration at sea level.

So, we assume for the Mirage III-C

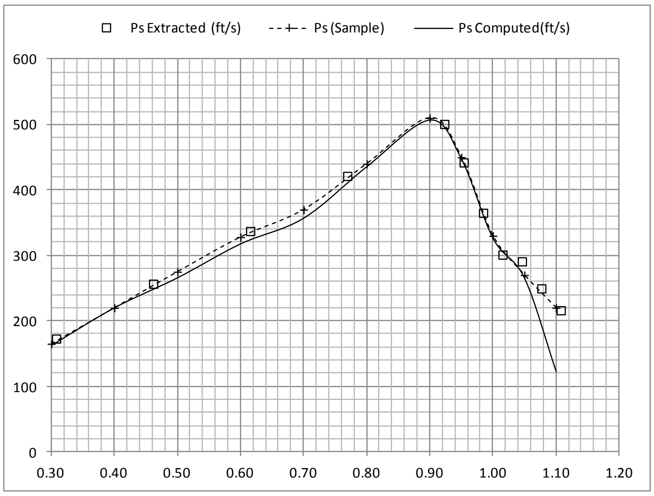
- Acceleration at 36,000ft performed at a GW=7,705kg
- Sustained load factor at a GW=7,600 kg

- Level flight Acceleration

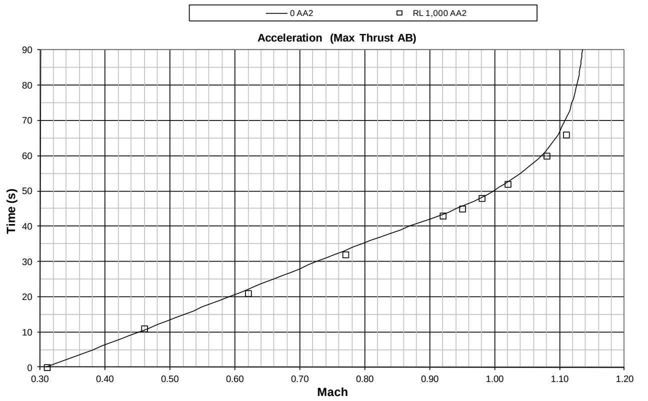
Acceleration at 1,000ft

Measures performed with a GW of 8,250 kg / 18,212 lbs

From acceleration figure (Speed along time), we compute the Excess Power (Extracted Ps), smooth it by sampling and compute Thrust value to fit.



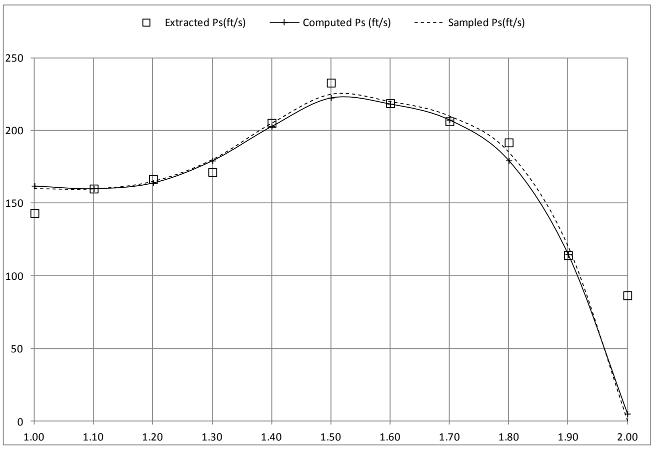
Then we compute acceleration fly path from the computed thrust and we get the following:



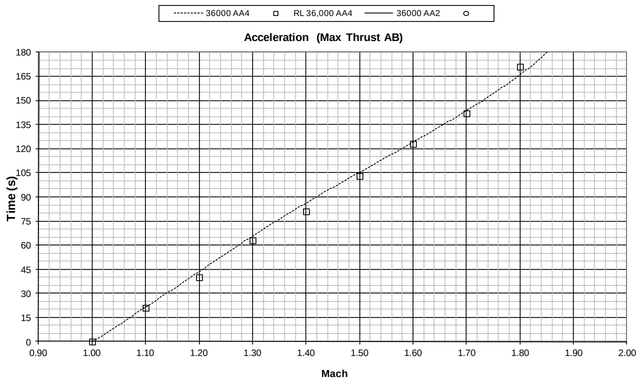
Acceleration at 36,000ft

Measures performed with a GW of 7,705 kg / 17,000 lbs

From acceleration figure (Speed along time), we compute the Excess Power (Extracted Ps), smooth it by sampling and compute Thrust value to fit.



Then we compute acceleration fly path from the computed thrust and we get the following:



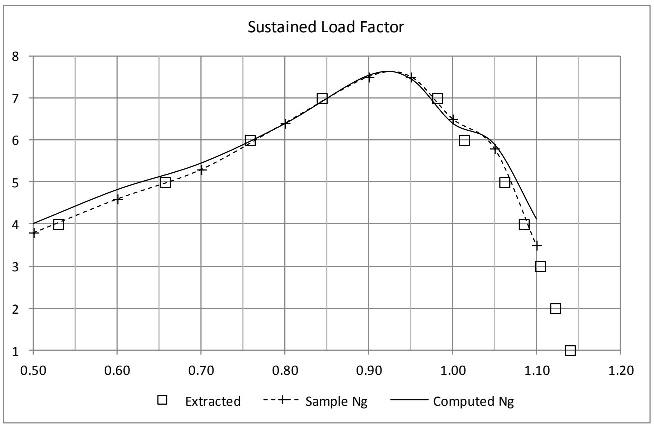
- Sustained Load Factor

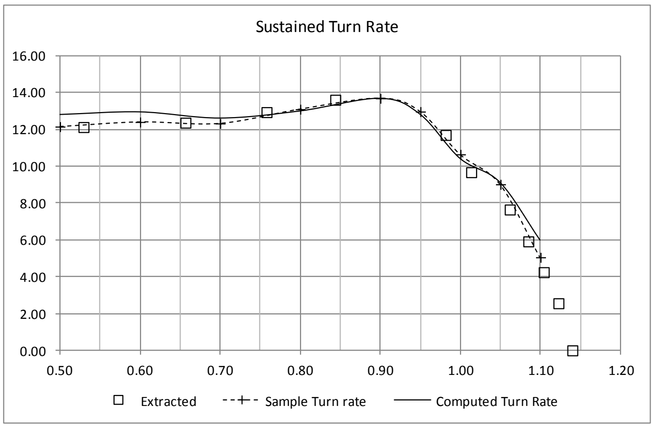
Measures performed with a GW of 7,600 kg / 16,780 lbs

Sustained Load Factor at 0ft.

Here the sustained load factor and turn rate are computed from thrust values deduced form SL acceleration path.

(Extracted values read from figures, then smoothed, compared to computed):

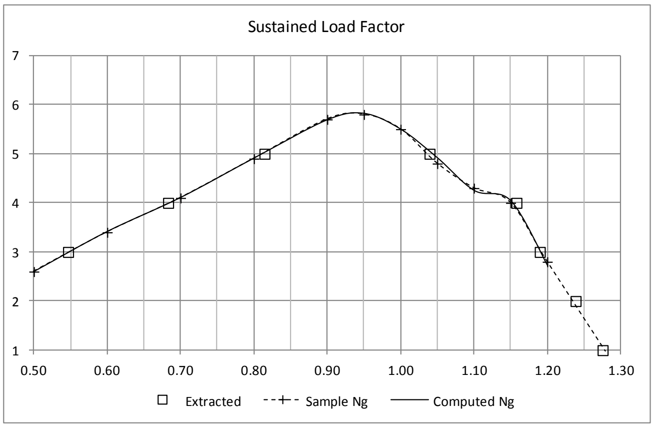


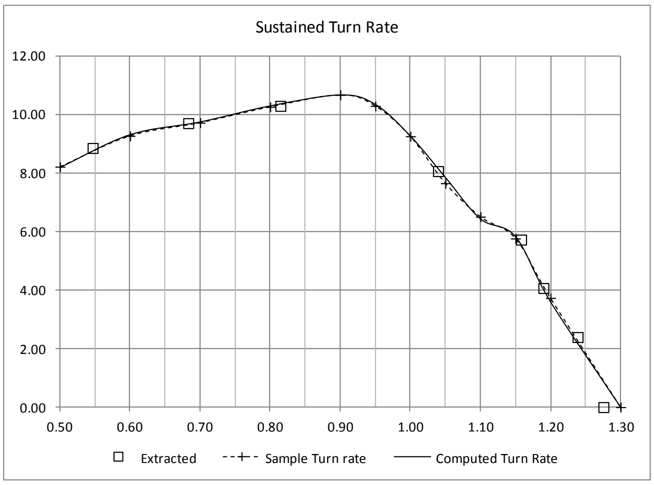


Mach	Sample Ng	Sample Turn rate	Computed Ng	Computed Turn Rate	Error Ng	Error T
0.50	3.80	12.15	4.01	12.82	5.44%	5.46%
0.60	4.60	12.40	4.81	12.96	4.61%	4.47%
0.70	5.30	12.32	5.44	12.62	2.68%	2.42%
0.80	6.40	13.10	6.38	13.01	-0.32%	-0.67%
0.90	7.50	13.69	7.53	13.70	0.39%	0.05%
0.95	7.50	12.97	7.45	12.83	-0.68%	-1.04%
1.00	6.50	10.65	6.39	10.43	-1.63%	-2.01%
1.05	5.80	9.02	5.89	9.13	1.53%	1.23%
1.10	3.50	5.05	4.12	6.00	17.61%	18.64%

Sustained Load factor at 10,000ft

Here, the thrust values are computed to fit the sampled sustained load factor and turn rate.

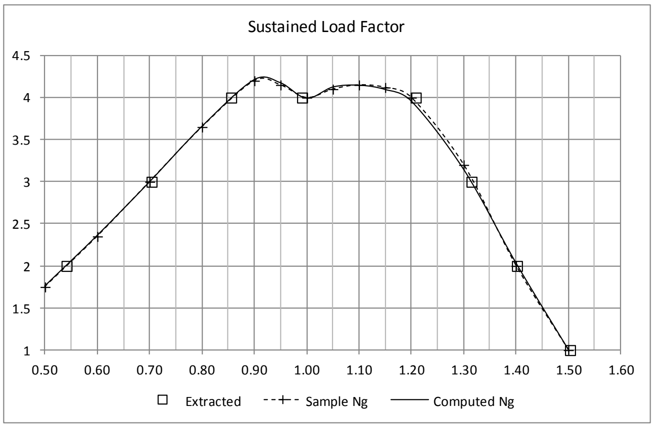


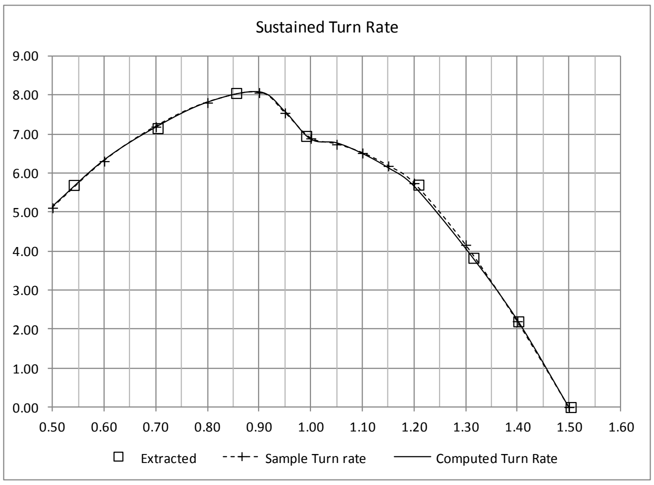


Mach	Sample Ng	Sample Turn rate	Computed Ng	Computed Turn Rate	Error Ng	Error T
0.50	2.60	8.22	2.59	8.19	-0.27%	-0.32%
0.60	3.40	9.27	3.41	9.31	0.39%	0.43%
0.70	4.10	9.72	4.11	9.75	0.22%	0.24%
0.80	4.90	10.26	4.91	10.30	0.30%	0.32%
0.90	5.70	10.67	5.70	10.67	-0.03%	-0.03%
0.95	5.80	10.29	5.83	10.35	0.52%	0.54%
1.00	5.50	9.26	5.51	9.27	0.15%	0.15%
1.05	4.80	7.65	4.92	7.86	2.54%	2.66%
1.10	4.30	6.51	4.26	6.44	-1.03%	-1.09%
1.15	4.00	5.76	4.04	5.83	1.08%	1.15%
1.20	2.80	3.73	2.72	3.60	-2.95%	-3.38%

Sustained load factor at 20,000ft

Here, the thrust values are computed to fit the sampled sustained load factor and turn rate.

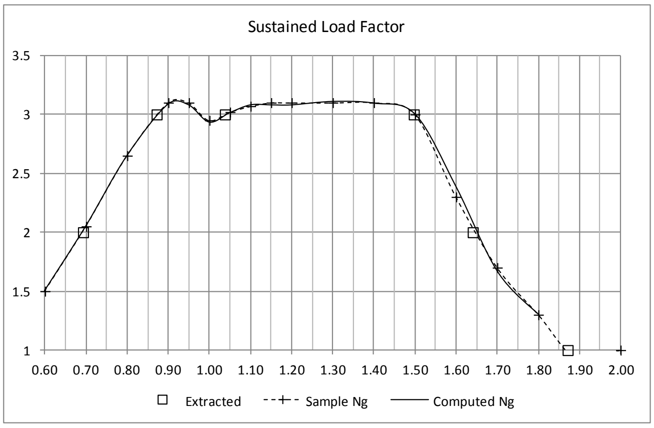


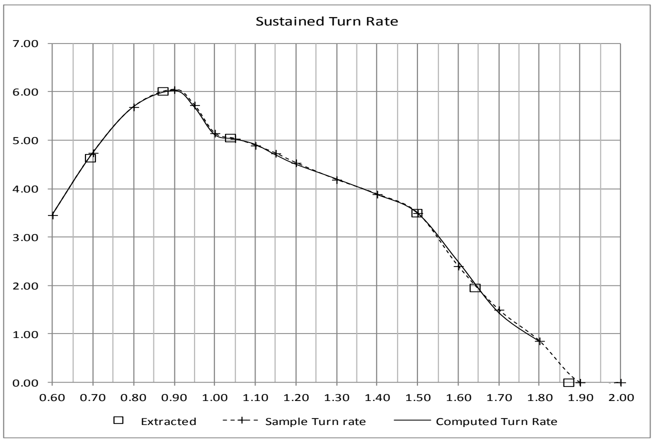


Mach	Sample Ng	Sample Turn rate	Computed Ng	Computed Turn Rate	Error Ng	Error T
0.50	1.75	5.11	1.76	5.14	0.46%	0.68%
0.60	2.35	6.30	2.36	6.33	0.37%	0.45%
0.70	3.00	7.19	3.00	7.18	-0.14%	-0.16%
0.80	3.65	7.80	3.66	7.82	0.14%	0.15%
0.90	4.20	8.06	4.21	8.08	0.28%	0.29%
0.95	4.15	7.54	4.18	7.59	0.60%	0.64%
1.00	4.00	6.89	3.99	6.87	-0.20%	-0.21%
1.05	4.10	6.73	4.12	6.78	0.58%	0.62%
1.10	4.15	6.51	4.15	6.51	-0.10%	-0.11%
1.15	4.12	6.18	4.09	6.14	-0.62%	-0.66%
1.20	4.00	5.74	3.96	5.67	-1.12%	-1.19%
1.30	3.20	4.16	3.14	4.08	-1.80%	-2.00%
1.40	2.00	2.20	2.03	2.24	1.45%	1.93%

Sustained load factor at 30,000ft

Here, the thrust values are computed to fit the sampled sustained load factor and turn rate.





Mach	Sample Ng	Sample Turn rate	Computed Ng	Computed Turn Rate	Error Ng	Error T
0.60	1.50	3.45	1.50	3.46	0.11%	0.20%
0.70	2.05	4.74	2.05	4.74	0.05%	0.07%
0.80	2.65	5.69	2.65	5.69	0.06%	0.07%
0.90	3.10	6.04	3.09	6.02	-0.29%	-0.32%
0.95	3.10	5.73	3.08	5.69	-0.52%	-0.59%
1.00	2.95	5.15	2.94	5.12	-0.43%	-0.49%
1.05	3.02	5.03	3.02	5.03	-0.07%	-0.08%
1.10	3.07	4.89	3.08	4.92	0.45%	0.50%
1.15	3.10	4.73	3.08	4.70	-0.52%	-0.59%
1.20	3.10	4.53	3.08	4.51	-0.52%	-0.59%
1.30	3.10	4.18	3.11	4.20	0.42%	0.47%
1.40	3.10	3.89	3.10	3.88	-0.05%	-0.06%
1.50	3.00	3.50	3.00	3.50	0.11%	0.12%
1.60	2.30	2.40	2.38	2.50	3.51%	4.31%
1.70	1.70	1.50	1.66	1.45	-2.19%	-3.36%
1.80	1.30	0.86	1.30	0.85	-0.26%	-0.64%

E. Mirage-III CJ

- Early version (up to 1971/74)

The Mirage-IIICJ early version keeps all data from Mirage-III C except its AoA limitations that are no more related to ADHEMAR system, but set to a value in AoA sector of 42, corresponding to 25.2 true AoA degrees.

- Late version (from 1971/74)

The late version of Mirage III-CJ is describes airframes retrofitted with ATAR-9C3 engines.

The late Mirage-IIICJ keeps all data from Mirage-III E except its weight (airframe, fuel and loads) that come from Mirage-III C and AoA limitations that are no more related to ADHEMAR system, but set to a value in AoA sector or 42, corresponding to 25.2 true AoA degrees.

F. Nesher - Mirage-5F

The Mirage 5F is assumed to have the same aerodynamic definition as the others (same hypothesis already made for Mirage-IIIC vs Mirage-IIIE).

Nesher engines are assumed to be ATAR-9C3 and then ATAR-9C5, but there is no known thrust change between the two sub versions, to thrust is assumed to be the same as the regular AdA Mirage-IIIE.

Nesher Incidence limitations are supposed to be identical to the one of the Mirage-IIICJ: a value in AoA sector of 42, corresponding to 25.2 true AoA degrees.

G. Appendix and Figures.

- Standard Atmosphere.

h (ft)	A(z) (M=1 ft/s)	rho(z) slug / ft^3	M=1 (m/s TAS)
0	1116.45	0.0023769	340.29
5,000	1097.09	0.0020481	334.39
10,000	1077.39	0.0017553	328.39
15,000	1057.32	0.0014957	322.27
20,000	1036.86	0.0012665	316.03
25,000	1015.98	0.0010652	309.67
30,000	994.67	0.0008894	303.18
35,000	972.9	0.0007366	296.54
40,000	968.08	0.0005851	295.07
45,000	968.08	0.0004601	295.07
50,000	968.08	0.0003618	295.07
55,000	968.08	0.0002846	295.07
60,000	968.08	0.0002238	295.07
65,000	968.08	0.000176	295.07
70,000	968.08	0.0001384	295.07
75,000	968.08	0.0001089	295.07
80,000	968.08	8.554E-05	295.07
85,000	968.08	6.653E-05	295.07
90,000	968.08	5.15E-05	295.07
95,000	968.08	4.011E-05	295.07
100,000	968.08	3.138E-05	295.07

- Corrected Air Speed (CAS).

CAS (Mach / ft)	0.00	0.50	1.00	1.25	1.50	2.00	3.00
0	0	330	660	825	1000	1325	1975
5,000	0	305	610	760	920	1225	1835
10,000	0	275	555	700	840	1125	1695
15,000	0	250	520	640	775	1025	1525
20,000	0	230	475	585	710	950	1430
25,000	0	205	430	525	640	865	1315
30,000	0	185	390	475	585	790	1200
35,000	0	165	350	435	525	720	1110
40,000	0	145	315	400	475	650	1000
45,000	0	130	280	360	440	590	890
50,000	0	115	250	325	390	535	825
55,000	0	105	220	285	350	475	725
60,000	0	93	195	255	320	425	635
65,000	0	83	174	227	285	386	565
70,000	0	75	157	205	257	342	510
75,000	0	66	139	182	229	304	454
80,000	0	60	126	165	207	274	410
85,000	0	54	114	149	186	248	370
90,000	0	48	101	133	166	221	330
95,000	0	42	89	116	146	194	290
100,000	0	40	83	108	136	181	270

H. Bibliography.

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- Computed Performance charts : NATOPS_FLIGHT_MANUAL-Mirage-IIICJ
- Computed Performance charts : NATOPS_FLIGHT_MANUAL-Mirage-IIIE
- Computed Performance charts : NATOPS_FLIGHT_MANUAL-Mirage-5F/Nesher

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